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Abstract

While a large literature has focused on the impact of parental investments on child cognitive development, very little is known about the children's own investments. Information on how children use their time separately from parents is probably little informative for babies and toddlers, but it becomes more and more important in later stages of life, such as adolescence, when children start to take decisions independently. The objective of this research is to explore and compare the impacts of time investments by parents and children on child cognitive outcomes. By using the Child Development Supplement of the PSID (Panel Study of Income Dynamics) 1997-2007 we show that own time investments have a significant effect on cognitive outcomes of children aged 11-15, while mothers' time inputs appear less important. For younger children, the impact of mothers' time is greater.

JEL Classification:J13, D1

Keywords: time-use, cognitive ability, child development, adolescence

1 Introduction

Several recent studies suggest that children's cognitive and non-cognitive outcomes are largely determined early in life and that returns on investments in early childhood are higher than those on investments at later stages, especially for disadvantaged children. Inputs from family's members as well as from the school system during early childhood

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play a very significant role in later cognitive, social, and behavioral outcomes (Carneiro and Heckman, 2003). The importance of the inputs vary with the age of the child. When children are very young the most important inputs come from families and schools, while when children get older, they begin to have more control on their actions and start to make decisions independently of their parents. Late childhood and adolescence is a period during which the influence of family investment decisions begins to decrease, whilst the effect of peers and the investments by the children themselves become more important factors in explaining their development. The economics literature considering children's investments in themselves is still very limited.

Cognitive development models for more mature children have been suggested by Carneiro, Cunha and Heckman (2003), and Cunha and Heckman (2008), while household models considering explicitly children as decision-makers in the household have been analyzed by Dauphin et al (2011). The economics literature insofare has acknowledged that the inputs in the cognitive production function have a different effect at different stages of the children's life, but they have not adapted the production function during adolescence to consider inputs by the children themselves. Empirical studies generally find that family and school inputs contribution in child development decreases with age and seem to suggest that there is less space for policy interventions in late childhood and adolescence. We would like to emphasize that this is probably true when we look at parents' and school inputs, but there can be other factors through which cognitive attainments of children can be improved late in childhood and adolescence. In our paper we focus on cognitive development during adolescence and we investigate the effect of the time mothers' spend with their children as well as the time children spend on their own doing formative activities. This allows us to assess whether children decisions on how to spend their time has an important role on their cognitive development process.

Using the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID), we measure cognitive abilities using a revised version of a set of intelligence tests developed by Woodcock and Johnson in 1977 (see Section 3 for more details). More specifically, we use two tests measuring reading abilities and a third test measuring mathematical skills. Assuming as a framework an augmented valued added specification for the cognitive production model, we regress the cognitive test on a set of contemporaneous and lagged inputs and on the corresponding lagged test (see Todd and Wolpin 2003 and 2007). The contemporaneous test and inputs are measured when children are between 11 and 15 years old, while the lagged test and inputs are measured 5 years earlier when the children are between 6 and 10 years old. The inputs we control for are the time the mother's spend with her child and the time the child spends on her own doing formative activities that improve cognitive development, which we call time inputs or time investments.

We find that the three cognitive tests are highly correlated with each other and follow the same cognitive production model. This allows to use the three cognitive tests as repeated measures of the child's latent cognitive ability and to control for child specific unobserved endowments. In this way we account of the endogeneity of the lagged test, which is caused by its dependence on the unobserved child specific ability endowment (See Section 4). We are also able to remove the bias which arises from unobserved family characteristics by exploiting the presence of sibling in the sample. Our estimation results show that the time children spend on their own doing formative activities during adolescence affects their test scores much more than the time inputs by their mother. On the contrary the time input by their mother during childhood matters more than the time input by the children.

2 Background

Several surveys have shown that parental investments (time and income) spent on children have important impacts on child cognitive and non cognitive outcomes (see Carneiro and Heckman 2003). However the different studies that have focused on maternal employment on child outcomes (Haveman and Wolfe 1995, Ermisch and Francesconi 2005) have reported mixed results. While the loss of the mother's child-care time has a negative effect on the child's cognitive outcomes, it is also the case that the additional income from mother's employment has positive implications for expenditures on goods consumed by the child.

Differences in the findings can be attributed to omission of relevant inputs in the cognitive production model and especially of variables measuring how children spend their time when they are not with their mother. When mothers go to work, it is relevant to control for inputs by other relatives, such as fathers and grandparents, as well as the types of schooling and child care (see Angelucci et al 2011, Del Boca and Pronzato 2012). The inputs that mothers use to substitute their time when working is especially important when children are very young. If mother's time is substituted with high quality child care, the impact of her absence may be less negative. Datta Gupta and Simonsen (2010) find that having a mother working does not impact negatively the cognitive child outcomes when high quality child care facilities are available. Similar results are reported by Brilli, Del Boca and Pronzato (2011).

When children get older, family's inputs become less important while peer groups are likely to have a larger impact on their development process (Liu et al. 2003, Todd and Wolpin 2007). In this stage, another important input in the children's development process is their own investment. As children grow into teenagers, they become active decision makers in their own process of development. However, children are seldom treated as decision makers in household behavioural models. They are usually assumed to have neither the capacity nor the power to influence the household decision process.

The literature on collective models has so far incorporated children through the "caring preferences" of their parents or has treated them as household public goods (Bourguignon, 1999 and Blundell et al., 2005). Empirically not many studies have included investment time the child devotes to herself. Carneiro, Cunha and Heckman (2003) formalize this issue, developing a model of cognitive and non-cognitive investments where also the child is a decision maker. They assume a three-periods model, where parents decide human capital investments on children in period 1 and starting from period 2 onward, when the child becomes adult, she alone decides her own education and work. However, this model does not consider the impact of specific activities of the child during her childhood.

Lundberg et al (2009), using child reports of decision-making and psychological and cognitive measures from the NLSY79 (National Longitudinal Survey of Youth 1979) Child Supplement, have examined the shared and sole decision-making in several domains of child activity. They find that the sole decision-making by the child and shared decision-making with parents are quite distinct and that child's ability to make sole decisions affecting her use of time and allocation of resources grows rapidly from ages 10 to 14. The likelihood of exerting independent decision power increases by approximately half between ages 12 and 13 and more than double between 12 and 14.

Given that during adolescence children begin to take decisions on their own on how to use their time, the cognitive production model for adolescents should include the time children spend on their own doing formative activities. The question is then how to define formative activities and consequently time investment by children. In the economics literature, there are no empirical papers that define time investment by children, while there are a few papers that have defined time investment by parents (see Price 2008, Hsin 2009). These papers consider time parents spend with their children in formative activities such as reading, doing home work, playing sports, and exclude activities which are usually considered detrimental or not beneficial to the child's development, as for example watching TV. Some attention to children's time use has been recently given in Mancini, Monfardini and Pasqua (2011) and Agee et al (2011). The first study focuses on the reading activity and spot imitation as a channel of intergenerational tranmission of the reading habit. The second paper specifies a household production function and considers among home inputs the time children spend reading, doing homework and staying with family, without distinguishing between time spent by the children on their own and time spent with an adult actively engaged. Children' cognitive and behavioral productivity is found to be greatest at ages 7-8 and decline thereafter, indicating that family and neighborhood contributions to child outcomes is weaker during adolescence.

From the psychological literature, we learn that reading habits have a positive effect on children's achievement, measured by vocabulary, reading comprehension and verbal fluency (Anderson, Wilson, and Fielding 1988; Taylor, Frye, and Maruyama 1990; Cunningham and Stanovich, 1991 and 1993). For instance, Searls, Mead and Ward (1985) evaluate the effects on reading abilities of different activities conducted at home by adolescents: watching TV, reading and doing homework. They find that children who watch TV extensively are among the poorest readers, even if they also report spending a great deal of time doing spare time reading or homework; homework activities increase reading abilities of adolescents, while spare time reading hours are associated with the highest reading performance, for all the age categories. A similar result is found in Anderson,Wilson and Fielding (1988). They study the relationship between out-of-school activities (as listening to music, playing sport and reading a book) on subsequent reading achievements; they find that among all the ways children spend their time, reading books was the best predictors of several measures of reading achievement.

Given that adolescents begin to take decisions on their own on how to spend their time and these decisions affect their cognitive developement, the production functions of cognitive achievements during childhood and adolescence are bound to be different. While childhood cognitive development depends mainly on innate abilities and investments that parents and schools choose to make on their children, development during adolescence becomes influenced also by investments decisions independently taken by the adolescents. "What lies at the core of adolescent cognitive development is the attainment of a more fully conscious, self-directed and self-regulating mind." (Steinberg 2005). During adolescence individuals become able to take decisions on their own and responsible for their actions, therefore their cognitive investments begin to depend on their own decisions, for example decisions on how much effort to invest in doing home work rather than watching television.

For this reason we model the cognitive achievement production function during adolescence considering inputs which reflect decisions by schools and families as well as by the adolescents themselves. Studying children allocation of time and its impact on their cognitive outcomes have important implications for public policy (Kooreman 2007). For example a social program that makes direct time or money investments in children will only be effective in increasing the distribution of child outcomes if these expenditures do not "crowd out" the investments the parents and children would be making in the absence of the program. Moreover certain aspects of teenage behavior are a source of concern to policy makers, teachers and parents: using drugs, dropping out of school, teenage pregnancy, smoking cigarettes, and drinking alcohol are examples.These behaviors bring health risks, large social costs, and may have long-lasting effects on individuals. On the other hand children's investments may impact in a significant way their schooling, health and later work results.

3 Data and sample selection

Our analysis relies on the Child Development Supplement (CDS), funded by the National Institute of Child Health and National Development (NICHD). The CDS covers a maximum of two children for a subsample of households interviewed in the Panel Study of Income Dynamics.[1] About 3500 children aged 0-12 (from about 2400 households) were first interviewed in 1997, and then followed in two subsequent waves, 2002/03 and 2007. The number of successful reinterviews was quite high: 91% in the second wave, 90% in the third one. The CDS collects information on cognitive and non-cognitive development of the sampled children, as well as their time diaries and other individual and family characteristics. All the household and parental variables included in the PSID survey are also available for the CDS children. In our estimation sample we include teenagers aged between 11 and 15 and living with both biological parents (about 800). To preserve sample

[1] The Panel Study of Income Dynamics is a USA longitudinal survey of a nationally representative sample of individuals and families, started in 1968 with a sample of 4800 families. It collects yearly individual information on economic, demographic, sociological, and psychological variables and well-being.

size, we pool two cohorts of children, born respectively in 1982-1986 (adolescents in 2002) and in 1987-1992 (adolescents in 2007).

3.1 Time investments

Crucial to our research question is the availability of detailed information on child's time use allocation for one randomly selected week-day and one randomly selected weekend-day. Time diaries contain for each day recording of activities performed in the 24 hours on a continuous basis.[2] Each spell of a given activity comes with information on its duration, location and on whether the activity was done by the child on her own, in presence of somebody not actively participating or in presence of somebody actively engaged.

This allows us to define a measure of weekly parental time input as well as a measure of weekly child's own time investment.[3] We measure the former as the time the parent spends actively engaged with the child reading, doing homework, doing arts and crafts, doing sport, playing, attending performances and museums, engaging in religious activity, having meals and talking with the child, or providing personal care for the child. This aggregate measure of parental investment corresponds to the parent's quality time defined by Price (2008).[4] It is meant to include all the activities in which either the child is the primary focus or there is a sufficient interaction between the parent and the child. The positive relationship between the frequency of activities such reading, playing or eating with children and their outcomes is well documented in the literature (see Price, 2008, section II for a concise review). The positive productivity of mother's and father's active time has also been very recently documented by Del Boca et al (2010).[5]

In order to take the novel perspective of the child's own investments in her development process, we select from the above listed activities those that improve the child human capital when performed autonomously by the child (i.e. either on his own or without any one actively engaged). The resulting aggregate measure of child's own investment includes - beside the time spent doing homeworks - all active leisure components such as reading, doing arts and crafts, doing sport, playing, attending performances and museums, engaging in religious activity. Both intuition and scientific evidence highlight that human capital includes components other than formal knowledge, as personal interaction skills that can be enhanced by time spent with friends or engaging in physical activities. Cardoso et al. (2010) consider socializing together with reading and studying as activities related to the acquisition of human capital, and opposed to passive leisure such as TV watching, often portrayed as detrimental and crowding out other useful activities. Felfe et al. (2011) report

[2] Activities are coded and registered from midnight of one day (00:00) to midnight of the following day (24:00), using a 24 hour clock. The ending time of an activity concides with the starting time of the following activity, so that there are no gaps in time.

[3] The weekly measure is obtained multiplying by five the week-day time, and summing the result with the weekend-day time multipied by two.

[4] Price (2008) derive parental time inputs from the parents time diaries, which are available in the American Time Use Survey.

[5] This finding is obtained estimating a structural model of household choices on a sample of single child households from the PSID CDS dataset.

that a positive link between participation in active leisure sport activities and educational attainment is well established for adolescence, and show that sport club participation during kindergarden and primary school has a positive effect on school performance.

In the upper part of Table 1 we display the composition of the child own's time inputs in childhood age (6-10) and adolescence (11-15) respectively. The total active time spent by children on their own increases of one hour a week on average (about 24%) across the two stages of their life. The reading and homework activities bring the largest contibution to this rise (about 25 minutes per week on average), followed by the playing category (with an average increase of about 20 minutes per week), most likely due to higher time spent doing computer games. On the contrary, sport and arts activities appear less frequently performed on average during adolescence compared to childhood. The bottom panel of the same table shows a sharp decrease of the mother time investments from the childhood to the adolescence period. Mothers spend on average about 9 hours and a half per week actively engaged with their children aged 6 to 10 years, but only 5 hours and 20 minutes when their children become adolescents. All categories of mother's time input diminish across the two child's life stages but talking.

Table 1. Mother's and child's time input composition

	Weekly time (hours)							
	Age range 6-10*				Age range 11-15**			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Own time inputs								
Total time	4.16	5.17	0	30.92	5.17	7.33	0	78.33
Reading	0.69	1.81	0	24	0.94	2.47	0	21.83
Homework	0.51	1.8	0	17.5	1.15	3.37	0	29
Playing	2.27	3.87	0	26.23	2.57	5.79	0	78.33
Arts and kraft	0.27	1.17	0	11.25	0.23	1.4	0	19.75
Sport	0.3	1.36	0	22.1	0.2	1.07	0	15
Attending performances	0	0	0	0	0.01	0.19	0	5.33
Attending museums	0	0	0	0	0	0	0	0
Religious activity	0.12	0.75	0	9.5	0.07	0.53	0	7.17
Mother's time inputs								
Total time	9.67	7.25	0	53.75	5.39	5.23	0	35.42
Reading	0.48	1.19	0	11.25	0.11	0.82	0	12.33
Homework	0.27	1.17	0	10.83	0.1	0.8	0	11.17
Playing	1.17	2.69	0	25.17	0.3	1.44	0	21.25
Talking	0.35	0.97	0	8.33	0.55	1.45	0	12.42
Arts and kraft	0.13	0.8	0	14.92	0.04	0.34	0	4.97
Sport	0.42	1.48	0	15	0.09	0.65	0	10.67
Attending performances	0.14	1	0	13.33	0.09	0.86	0	13.33
Attending museums	0.04	0.53	0	9.5	0	0	0	0
Religious activity	0.79	2.04	0	14.32	0.77	2.3	0	25.47
Meals	4.65	3.2	0	22.17	3.11	3.06	0	27.25
Personal care	1.24	2.55	0	24.17	0.24	1.17	0	16.17
Number of Observations: 807								

*evaluated on years1997-2002, pooled

**evaluated on years 2002-2007, pooled

3.2 Cognitive outcomes

The cognitive tests come from the Woodcock-Johnson Revised Tests of Achievement (WJ-R), "a well-established and respected measure that provides researchers with information on several dimensions of intellectual ability" (CDS User Guide). The CDS provides three of such cognitive test scores measuring reading and mathematics achievements: the Letter-Word Identification, Passage-Comprehension, and Applied-Problems test scores. These tests were administered to respondents aged 6 years and older by the interviewer, following a standardized administrative protocol and adjusting the test by difficulty according to the respondent age (see CDS User Guide for details). Each of these three tests provides a score which is a measure of the cognitive ability. The Letter-Word Identification Score (LWS) measures symbolic learning (matching pictures with words) and reading identification skills (identifying letters and words). It starts from the easiest items (identification of letters and pronunciation of simple words), progressing to the more difficult items. The Passage Comprehension Score (PCS) assesses comprehension and vocabulary skills through multiple-choice and fill-in-the-blank formats. The Applied Problems Score (APS) measures mathematical skills in analyzing and solving practical problems. The test score are available in both raw and standardized formats. The former essentially counts the number of items correctly answered, while the latter are obtained standardizing the raw scores according to the respondent's age.[6] We use the standardized measures throughout our analysis.

3.3 Time investments and cognitive ability: preliminary evidence

In Tables 2 and 3 we provide descriptive evidence on the link between time investments and children cognitive outcomes. In Table 2 we look at the differences between average test scores for adolescents dividing them in two groups: those receiving a high level of inputs from their mother (higher than the average) and those receiving a low level of inputs (lower than the average). It can be noticed that children receiving low time investments from their mother in adolescence have essentially the same outcomes in adolescence as children receiving high time investments, while the time spent with the mother actively engaged in childhood is associated with significant differences for two out of the three cognitives measures considered during the adolescence period.

[6] The age standardization process allows for comparison of children of different ages, eliminating the discrepancy in the results due to age differences.

Table 2. Differences in average test scores by time inputs received by mother

	LWS		PCS		APS	
Contemporaneous input (age 11-15)						
	Obs	Average	Obs	Average	Obs	Average
Sample	807	105.404	806	103.651	806	106.610
Time inputs by mother						
High (higher than average)	316	106.203	315	104.714	316	107.168
Low (lower than average)	491	104.89	491	102.970	490	106.251
Difference		1.313		1.745		0.917
St. Error		1.239		1.092		1.118
Lagged input (age 6-10)						
	LWS		PCS		APS	
	Obs	Average	Obs	Average	Obs	Average
Sample	807	105.404	806	103.651	806	106.610
Time inputs by mother						
High (higher than average)	345	106.423	344	105.974	344	108.096
Low (lower than average)	462	104.643	462	101.922	462	105.504
Difference		1.780		4.052**		2.592**
St. Error		1.222		1.069		1.100
Two sided t test for H_0: Difference=0						
*, **, *** statistically significant at 10%, 5%, 1% level respectively						

Turning to child's own investments in Table 3, the pattern is reversed, and contemporaneous inputs display a stronger relationship with adolescents' outcomes with respect to past inputs. The highly significant differences in the test scores between children with high time investments in human capital building activities and those with low time investments strongly support our next investigation about the relevance of autonomous decisions taken by children in this stage of life.

Table 3 Differences in average test scores by child own time inputs

Contemporaneous input (age 11-15)						
	LWS		PCS		APS	
	Obs	Average	Obs	Average	Obs	Average
Sample	807	105.404	806	103.651	806	106.610
Child time inputs						
High (higher than average)	276	107.573	276	106.58	225	109.391
Low (lower than average)	531	104.277	530	102.126	581	105.534
Difference		3.296***		4.453***		3.858***
St. Error		1.271		1.113		1.209
Lagged input (age 6-10)						
	LWS		PCS		APS	
	Obs	Average	Obs	Average	Obs	Average
Sample	807	105.404	806	103.651	806	106.610
Child time inputs						
High (higher than average)	309	107.162	309	105.172	308	107.711
Low (lower than average)	498	104.313	497	102.706	498	105.930
Difference		2.849**		2.465**		1.781^
St. Error		1.241		1.094		1.122
Two sided t test for H_0: Difference=0						
*, **, *** statistically significant at 10%, 5%, 1% level respectively						

4 Modelling cognitive achievement production function during adolescence

We model the cognitive achievement production function during adolescence considering inputs which reflect decisions by schools and families as well as by the adolescents themselves. We also take account that the cognitive development is a cumulative process by considering both contemporaneous and past investments.

Accordingly we adopt the following cognitive production function for adolescents aged between 11 and 15 years old

$$Y_{ijt} = F_t(\mathbf{X}_{ijt}, \mathbf{X}_{ijt-5}, \mathbf{X}_{ijt-10}, \mu_{ij}) \quad (1)$$

where the outcome Y_{ijt} is a test score measuring the cognitive achievement for adolescent i in family j at t years old, t=11,...,15, and the arguments are given by

- the vector of contemporaneous cognitive investments during adolescence by the child herself, X^C_{ijt}, her family, X^F_{ijt}, and her school, $X^S_{ijt}, \mathbf{X}_{ijt} = [X^C_{ijt}, X^F_{ijt}, X^S_{ijt}]$;
- the corresponding vector of inputs during late childhood (5 years earlier), $\mathbf{X}_{ijt-5} = [X^C_{ijt-5}, X^F_{ijt-5}, X^S_{ijt-5}]$;

- the corresponding vector of inputs during early childhood (10 years earlier), $\mathbf{X}_{ijt-10} = [X^C_{ijt-10}, X^F_{ijt-10}, X^S_{ijt-10}]$;
- her cognitive endowment (innate ability) μ_{ij}.

This production function is similar to the one considered by previous work on child cognitive development with the main difference that it adds the investments made by the children themselves beside the usual inputs by families and schools (see Todd and Wolpin 2003 and 2007).

By assuming that the production function is additive separable, linear in its arguments and invariant during the adolescent period from 11 to 15, it can be rewritten as

$$Y_{ijt} = \beta_0 + \beta_1 \mathbf{X}_{ijt} + \beta_2 \mathbf{X}_{ijt-5} + \beta_3 \mathbf{X}_{ijt-10} + \mu_{ij} + \epsilon_{ijt}, \tag{2}$$

or more explicitly as

$$\begin{aligned} Y_{ijt} \;=\; & \beta_0 + \beta^C_1 X^C_{ijt} + \beta^F_1 X^F_{ijt} + \beta^S_1 X^S_{ijt} + \beta^C_2 X^C_{ijt-5} + \beta^F_2 X^F_{ijt-5} \\ & + \beta^S_2 X^S_{ijt-5} + \beta^C_3 X^C_{ijt-10} + \beta^F_3 X^F_{ijt-10} + \beta^S_3 X^S_{ijt-10} + \mu_{ij} + \epsilon_{ijt}, \end{aligned} \tag{3}$$

where β_0 is the intercept, $\beta_1 = [\beta^C_1, \beta^F_1, \beta^S_1]$, $\beta_2 = [\beta^C_2, \beta^F_2, \beta^S_2]$ and $\beta_3 = [\beta^C_3, \beta^F_3, \beta^S_3]$ are vectors of coefficients corresponding to contemporaneous and 5-year and 10-year lagged inputs from children themselves, families and schools, and ε_{ijt} is an additive random error term which reflects a potential error in the test score unrelated with the inputs and the innate ability. Model (3) is what Todd and Wolpin (2003) call the *cumulative model,* that is a model where the outcome at age t, during adolescence, depends on inputs at different points of the child's life, more specifically in early childhood, late childhood and adolescence.

In our empirical application we are unable to measure inputs in early childhood and therefore we have to drop these inputs from the model. This is a minor issue for cognitive investments during early childhood by the child herself, X^C_{ijt-10}, because very young children spend very little time without any adult actively engaged in what they are doing. On the contrary, the omission of inputs from school and parents in early childhood can be relevant; but, since our final estimation uses a sibling difference approach, we are effectively controlling for all early childhood inputs which are invariant between siblings.

We measure family investments by looking at the time the mother spends actively engaged with her child, whereas we measure children investments in their own cognitive development by the time they spend in formative activities on their own (see Section 3 for details on these definitions). These time inputs are measured in two points in the child's life, when she is adolescent between 11 and 15 years old and 5 years earlier when she still in her childhood and aged between 6 and 10. Finally we also control for sex, marital status of the mother at birth, ethnicity, children birth order, number of siblings, mother's education, birth cohort 1982-86 (1987-1991), and for mother's and child's age. We do not explicitly consider school inputs, but, as in Rosenzweig and Wolpin's (1994), we assume that there are no significant differences in the school inputs between two siblings who grow up in the same family and live in the same neighborhood, so that we can adopt a family fixed effect estimation to take account of the omission of school inputs.

Given two siblings i and $i\prime$ and differentiating the cumulative model produces

$$DY_{ijt} = \beta_1^C DX_{ijt}^C + \beta_1^F DX_{ijt}^F + \beta_2^C DX_{ijt-5}^C + \beta_2^F DX_{ijt-5}^F + D\mu_{ij} + D\epsilon_{ijt}. \quad (4)$$

where DA_{ijt} denotes the difference of the variable A between sibling i and $i\prime$.[7] Note that, since we are assuming that siblings have equal school inputs in early childhood, late childhood and adolescence and that inputs during early childhood by schools, families and children themself do not vary between siblings, differences in school inputs and in early child inputs cancels out from the model. Furthermore, if the child endowment μ_{ij} is composed by a family and a child specific component, $\mu_{ij} = \mu_j^F + \mu_{ij}^C$, then $D\mu_{ij}^F$ also cancels out. Consequently, using family fixed effect estimation, we implicitly allow the cognitive achievement to depend on school inputs and the inputs to depend on family endowments, but we are unable to take account of the possible dependence of inputs on child specific endowments or on past cognitive achievements. Parents' and children's own time investments may depend on the child's past cognitive tests. For example, a bad test obtained in the past can lead parents to invest more time with their children to improve their performance. To control for this dependence between lagged test and inputs, we add the lagged cognitive test as explanatory variable in the cumulative model, which yields the *augmented valued added model* (as defined by Todd and Wolpin 2007)

$$Y_{ijt} = \beta_0 + \beta_1 \mathbf{X}_{ijt} + \beta_2 \mathbf{X}_{ijt-5} + \rho Y_{ijt-5} + \mu_{ij} + \epsilon_{ijt}. \quad (5)$$

As done before for the cumulative model, we differentiate the model (5) to control for school inputs and family endowments and characteristics which are invariant between siblings

$$\begin{aligned} DY_{ijt} &= \beta_1^C DX_{ijt}^C + \beta_1^F DX_{ijt}^F + \beta_2^C DX_{ijt-5}^C + \beta_2^F DX_{ijt-5}^F \quad (6) \\ &\quad + \rho DY_{ijt-5} + D\mu_{ij}^C + D\epsilon_{ijt}, . \end{aligned}$$

and use family fixed effect estimation. The main issue with this estimation is the endogeneity of the lagged cognitive test variable. If child's unobserved ability enters the production function each period and not through a one-time initial endowment process, a positive correlation will exist between the (sibling differenced) lagged cognitive test, DY_{ijt-5}, and the (sibling differenced) child specific endowment component, $D\mu_{ij}^C$. This can cause an upward bias for ρ which can contaminate the input coefficients as well (Andrabi et al., 2011). By using observations on three different cognitive tests available for each child and

[7] The difference in the varaibles between two siblings is taken in the same calendar period, meaning that two siblings can have different ages but both of them must be aged between 11 and 15.

assuming the same cognitive production model for each of the tests, which we denote by the subscript k,

$$Y_{kijt} = \beta_1^C X_{ijt}^C + \beta_1^F X_{ijt}^F + \beta_2^C X_{ijt-5}^C + \beta_2^F X_{ijt-5}^F + \rho Y_{kijt-5} + \mu_{ij} + \epsilon_{kijt}, \quad (7)$$

we can use individual fixed effect estimation to control for child specific endowment that may differ across siblings. Note that the inputs do not vary across the three tests implying that individual fixed effect estimation can produce estimates for ρ but not for $\beta_1^C, \beta_1^F, \beta_2^C$ and β_2^F. Nevertheless, we can replace ρ with its estimate in

$$DY_{kijt} - \rho DY_{kijt-5} = \beta_1^C DX_{ijt}^C + \beta_1^F DX_{ijt}^F + \beta_2^C DX_{ijt-5}^C + \beta_2^F DX_{ijt-5}^F + D\mu_{ij}^C + D\epsilon_{kijt}, \quad (8)$$

and use family fixed effect estimation to produce estimates for the coefficients $\beta_1^C, \beta_1^F, \beta_2^C$ and β_2^F. Thanks to this two-step estimation we obtain results that are purged of the bias induced by the lagged test regressor and are consistent under the assumption that the whole dependence between inputs and child's innate ability is channelled through observed achievements or family endowments or characteristics that are invariant between siblings. We are actually not the first to assume that different cognitive test scores are related to a same latent cognitive ability and to use the multiplicity of measures to solve the issue of endogeneity of the lagged test. For example Cunha and Heckman (2008) use multiple measures of tests and inputs, which are available in their dataset, to derive three latent measures corresponding to cognitive and non-cognitive abilities and investment. Furthermore, they use multiple measures of tests and inputs to instrument the lagged tests and inputs in their cognitive developement model (see Madansky 1964 and Pudney 1982 for more details on this other type estimation). Our procedure impose some different restrictions, but it is simpler and has the advantage to distinguish between parents and children inputs and therefore allows us to evaluate the contribution of children decisions on their cognitive development process. To sum up, the main restrictions imposed by our model are: (1) school inputs do not vary between siblings; (2) there is no difference between siblings in inputs by parents and children in early childhood (0-5), (3) the three test scores are equal to the child's latent cognitive ability plus a white noise error, (4) children and mothers inputs are independent of the child specific unobserved innate ability (but we allow them to depend on child innate ability endowment that is invariant between siblings and on the child's lagged cognitive ability test).

5 Estimation results of the cognitive production model

We begin by estimating the augmented valued added model (5) for cognitive abilities measured during adolescence (at 11-15 years old). We use the ordinary least squares method, but we correct the variance of the estimator to take account of the correlation of the errors between siblings. In Table 4 we report the estimation results separately for the three standardized test scores LWS, PCS and APS.

Results do not change significantly across the three tests and the Chow test does not reject the equality of the cofficients at standard levels of significance. Given that the cognitive abilities measured by the three tests seem to follow the same cognitive production model, we also report the results obtained by pooling toghether the observations on the three tests to estimate a test-invariant production model (see last column of Table 4) and we focus our discussion on this model. Looking at time investments during adolescence (when the child is between 11 and 15 years old), cognitive abilities are significantly affected by the child's own investment but not by the mother's time investment. On the contrary, looking at time investments during childhood (when the child is between 6 and 10 years old), the mother's time investment matters more than the child's own time investment. Notice that the mother's time investment on her child decreases from about 10 hours per week to 5 hours per week when children move from childhood to adolescence. This implies that children get more authonomy in deciding how to invest their time, hence the importance of their own time investments during adolescence in explaining their cognitive test results.

Although statistically significant, time investments effect are not huge. An increase of one hour per week in the mother's time input during childhood leads to a increase of about 2% of a standard deviation of the cognitive test, while an increase of one hour in the child's own time input during adolescence leads to an increase of about 1% of a standard deviation.

Beside mother's and child's own time investments, variables that are statistically significant at 5% level in explaining cognitive tests during adolescence are the lagged test measured 5 years earlier, the number of years of education of the mother and the dummy for white ethnicity, which are all positively associated with the child's cognitive tests. Furthermore, at 10% level of significance, the birth order seems also to matter and children with low birth order seem to have better cognitive tests results.

Table 4. OLS estimation results

	LWS		PCS		APS		Test-invariant	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Lag(test)	0.542***	0.053	0.476***	0.067	0.578***	0.037	0.526**	0.040
Mother time	0.004	0.007	0.013*	0.007	0.002	0.007	0.006	0.005
Child time	0.013**	0.006	0.023***	0.007	0.019***	0.005	0.018***	0.005
Lag(Mother time)	0.006	0.006	0.014**	0.006	0.008	0.005	0.009**	0.004
Lag(Child time)	0.010	0.008	0.002	0.007	-0.003	0.006	0.003	0.005
Child age	-0.520	0.573	0.059	0.606	-1.143**	0.490	-0.544	0.413
Child age sq	0.018	0.022	-0.001	0.023	0.041**	0.019	0.020	0.016
Mother age	0.072	0.086	0.259**	0.107	-0.012	0.093	0.106	0.072
Mother age sq.	-0.001	0.001	-0.003**	0.001	0.000	0.001	-0.001	0.001
Male	-0.172**	0.073	-0.020	0.083	0.007	0.071	-0.056	0.053
Birth order	-0.060	0.057	-0.057	0.065	-0.101*	0.054	-0.072*	0.042
Born 1982-1987	-0.036	0.085	-0.107	0.091	0.124	0.078	-0.013	0.063
Married	-0.071	0.161	-0.109	0.176	0.000	0.144	-0.058	0.134
White	0.128	0.095	0.158	0.110	0.304***	0.087	0.200***	0.076
siblings	0.027	0.056	-0.007	0.062	0.062	0.060	0.029	0.041
Mother years educ	0.037*	0.019	0.060***	0.019	0.036*	0.019	0.044***	0.013
Constant	1.285	4.120	-7.052	4.532	7.173*	3.668	0.499	3.065
R-squared	0.459		0.418		0.519		0.448	
F test (regression)	12.87		16.390		29.41		27.90	
p-value	0.000		0.000		0.000		0.000	
N. observations	807		807		807		2421	

Note: The tests are standardized to have zero mean and unit variance.

Since larger time investments can be correlated with family and school characteristics such as having a better and more stimulating home and school environment, it is possible that the positive effect of time inputs be overestimated. To take account of this potential bias, we control for unobserved school and family characteristics that are invariant between siblings by using the family fixed effect estimation (see Table 5). We report the estimates obtained separately for the three standardized test scores LWS, PCS and APS as well as the estimates of a test-invariant production model. As in the case of the least square estimation, results do not change significantly across the three tests and we focus our discussion on the results for the test-invariant production model (See last column of Table 5). We find again that mother's time inputs are relevant during childhood but not during adolescence, while child's own investments are important only during adolescence. The lagged test remains still highly significant, while the mother's education and the dummy for white ethnicity are not identified by the model because they are invariant between siblings and therefore captured by the family fixed effect.

Except for the coefficients of the lagged test, mother's input during childhood and child's own time inputs during adolescence, there are no other covariates statistically significant in explaining cognitive tests during adolescence. Although still statistically significant, the coefficients of the lagged test and of the mother's input during childhood are smaller in size. This seems to indicate that there is an issue of endogeneity and a bias of the ordinary least squares estimation, which is caused by the dependence of the explanatory variables on unobserved family and school characteristics that are invariant between siblings.

Table 5. Family fixed effects - not corrected

	LWS		PCS		APS		Test-invariant	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Lag(test)	0.323***	0.059	0.295***	0.067	0.394***	0.061	0.354***	0.037
Mother time	-0.005	0.009	0.014	0.009	-0.007	0.009	0.002	0.006
Child time	0.011	0.008	0.014*	0.009	0.017***	0.006	0.015***	0.005
Lag(Mother time)	0.005	0.007	0.010	0.008	0.013	0.008	0.010*	0.005
Lag(Child time)	0.017**	0.008	-0.002	0.008	-0.001	0.007	0.005	0.005
Child age	-0.739	0.533	0.382	0.685	-1.085*	0.555	-0.461	0.436
Child age sq.	0.028	0.021	-0.013	0.027	0.040*	0.021	0.018	0.017
Mother age	-0.277	0.353	0.133	0.349	0.012	0.298	-0.041	0.206
Mother age sq.	-0.003	0.003	-0.002	0.003	0.000	0.002	-0.002	0.002
Male	-0.265***	0.095	-0.028	0.101	-0.021	0.096	-0.105	0.068
Birth order	-0.012	0.124	-0.002	0.152	-0.043	0.121	-0.013	0.101
Constant	19.991	13.128	-4.890	10.995	7.511	10.397	7.372	6.627
Sibl. correlation	0.956		0.605		0.543		0.802	
F test	4.55		2.75		5.170		9.670	
p-value	0.000		0.002		0.000		0.000	
N. sibl. groups	220		220		219		220	
N. observations	426		420		427		1273	

Note: The tests are standardized to have zero mean and unit variance.

The question is then whether the family fixed effect estimation is able to control for all unobserved characteristics that are associated with the explanatory variables and relevant in explaining the cogntive tests. It is certain that family fixed effect estimation fails to control for innate individual abilities that differ between siblings. Since both cognitive tests measured during adolescence and during childhood are likely to depend on these individual abilities, we have a further issue of endogeneity. But, as explained in Section 4, we can use the three test scores as three repeated measures on the same cognitive ability and estimate a test-invariant production model using an individual fixed effect estimation.

In the upper part of Table 6 we report the estimation results for the individual fixed effect estimation obtained pooling the three tests, which obviously identifies only the coefficient of the lagged test because all the other variables are invariant across tests. The coefficient of the lagged test reduces further and this confirms that the family fixed effect estimation presented in Table 5 is inadequate to control for unobserved individual characteristics that differ between siblings. Nevertheless, when we consider the family fixed effect estimation obtained in the second-step to identify the effect of the remaining variables, in the lower part of Table 6, we find that time investments coefficients remain almost unaltered in size and statistical significance. An increase of one hour per week in the mother's time investment during childhood rises the test score of 1% of a standard deviation, while an equivalent increase in the child's own time investment during adolescence leads to a 1.4% of a standard deviation rise in the test score. The only other statistically significant variable, beside the lagged test and the time inputs, is the gender of the child. Boys seems to obtain lower test scores than girls and the difference is significant at 10% level.

Table 6. Two-step estimation results

	Test invariant	
	Coef.	SE
First step		
Lag(Test)	0.275***	0.033
Second step		
Mother time	0.000	0.007
Child time	0.014**	0.005
Lag(Mother time)	0.010*	0.005
Lag(Child time)	0.006	0.005
Child age	-0.370	0.441
Child age sq.	0.015	0.017
Mother age	-0.056	0.211
Mother age sq.	-0.002	0.002
Male	-0.106	0.069
Birth order	-0.006	0.102
Constant	7.590	6.807
N. observations	1273	
N. groups	220	
Sibling correlation	0.836	
F test (regression)	1.530	
p-value	0.122	

Note: The tests are standardized to have zero mean and unit variance.

In conclusion, the main results of our empirical analysis may be summarized in following three main points. First, the quality time children spend on their own during adolescence explains their test scores much more than the quality time the mother's spends with them during adolescence. Second, time inputs during childhood by the mother are relevant to explain adolescents' test scores, while children's own time investment during childhood are not as important as the quality time they spend with their mother. Third, there is a large persistence of the test score and this implies that, if a child obtains a bad result on a test during childhood, there is a strong probability that she will get again a bad result during adolescence. This is obviously in part explained by innate individual abilities. In fact, once we control for the unobserved abilities using individual fixed effect estimation, we find a much reduced effect of the lagged test on the contemporaneous test.

6 Conclusions

While a large literature has focused on the impact of parental time on child outcomes, very little is still known on the impact of children's own time investments in their development process. In our paper, we analyze the cognitive achievement production function during adolescence considering inputs which reflect decisions by schools and families as well as by the adolescents themselves.

In our empirical analysis, we control for the endogeneity of parents' and children's time investments, which is caused by unobserved inputs, by controlling for family fixed effect and assuming that unobserved inputs do not vary between siblings. Even after controlling for family fixed effect, we still have to take account of the endogeneity of the lagged test, which is caused by its dependence on the unobserved individual-specific skill endowment. We deal with this issue by applying a child-specific individual effect estimation, which makes use of the multiplicity of cognitive tests available in our data.

Our estimation results show that the time investments by children during adolescence affect their test scores much more than the time input by their mother. On the contrary, the time input by their mother during childhood matters more than the time inputs by the children. These results seem to suggest that a way to improve cognitive abilities of adolescents is by influencing their decisions and their investments in formative activities.

Studying children's allocation of time and its impact on their cognitive outcomes have important implications for public policy. Effective policies to influence adolescents' behaviors require then a deep understanding of what teenagers prefer, what resources they have available, and how they make their time allocation decisions.

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7 Appendix

Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Tests				
LWS	105.404	17.18453	46	183
PCS	103.6514	15.13685	37	187
APS	106.6104	15.48615	52	166
Time inputs				
Mother's time input	5.389033	5.229986	0	35.41667
Lag(Mother's time input)	9.673131	7.252047	0	53.75
Child own time input	5.168401	7.33306	0	78.33334
Lag(Child own time input)	4.157765	5.17112	0	30.91667
Control variables				
age	12.99009	1.423797	11	15
mother's age	41.20942	5.242696	27	58
male	0.483271	0.50003	0	1
mother married at birth	0.864932	0.342008	0	1
white	0.662949	0.472996	0	1
siblings	2.686493	0.790517	2	5
birth order	1.906832	0.872473	1	5
mother's years education	13.2875	2.632205	0	17
born 1982-1987	0.489467	0.500199	0	1
Number of observations	807			